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# Space systems — Fluid characteristics, sampling and test methods —

# Part 2:
Hydrogen

*Systèmes spatiaux — Caractéristiques des fluides, échantillonnage et méthodes d'essai —*

*Partie 2: Hydrogène*

ICS 49.140

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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 15859 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15859-2 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

ISO 15859 consists of the following parts, under the general title *Space systems — Fluid characteristics, sampling, and test methods*:

— *Part 1: Oxygen*

— *Part 2: Hydrogen*

— *Part 3: Nitrogen*

— *Part 4: Helium*

— *Part 5: Nitrogen tetroxide propellants*

— *Part 6: Monomethylhydrazine propellant*

— *Part 7: Hydrazine propellant*

— *Part 8: Kerosine propellant*

— *Part 9: Argon*

— *Part 10: Water*

— *Part 11: Ammonia*

— *Part 12: Carbon dioxide*

— *Part 13: Breathing air*

# Introduction

This International Standard specifies limits for the composition of hydrogen and establishes the fluid sampling and test methods for hydrogen intended for use as a fuel in propellant systems of space systems. The purpose of this International Standard is to establish uniform requirements for the composition of hydrogen and the sampling and test methods for hydrogen used in the servicing of launch vehicles, spacecraft, and ground support equipment.

Fluid operations at a spaceport or launch site may involve a number of operators and supplier/customer interfaces, from the fluid production plant to the delivery to the launch vehicle or spacecraft. The fluid composition limits specified in this International Standard are intended to define the purity and impurity limits of the fluid for loading into the launch vehicle or spacecraft. The fluid sampling and test methods included in this International Standard are intended to be applied by any operator. The fluid sampling and test methods presented in this International Standard are acceptable methods for verification of the fluid composition limits.

# Space systems — Fluid characteristics, sampling and test methods —

# Part 2:
Hydrogen

## 1 Scope

This part of ISO 15859 specifies limits for the composition of hydrogen and defines the fluid sampling and applicable test methods for verification of hydrogen composition. This International Standard establishes acceptable composition, test, and sampling requirements. This part of ISO 15859 applies to the following types and grades of hydrogen.

**CAUTION — Hydrogen is an asphyxiant and is volatile. Human contact with liquid hydrogen will result in severe injury. Care should be taken in the handling and storage of liquid hydrogen to prevent contact with the human body and with materials that are not compatible with hydrogen.**

- Type I: gaseous
  - grade A: fuel;
  - grade F: fuel;
- Type II: liquid
  - grade A: fuel;
  - grade F: fuel.

This part of ISO 15859 is applicable to hydrogen used in both flight hardware and ground facilities, systems, and equipment. It is applicable to influents only to the extent specified herein.

This part of ISO 15859 is applicable to any sampling operation required to ensure that, when the fluid enters the launch vehicle or spacecraft, the fluid composition complies with the limits provided hereafter or with any technical specification agreed to for a particular use.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 15859. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 15859 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 8402:1994, *Quality management and quality assurance — Vocabulary*

ISO 14687:1999, *Hydrogen fuel — Product specification*

# 3 Terms and definitions

For the purposes of this part of ISO 15859, the terms and definitions given in ISO 8402 and the following apply.

**3.1**
**total hydrocarbon content (as methane)**
the single carbon atom equivalent

**3.2**
**verification tests**
analyses performed on the fluid in the container, or a sample thereof, which is representative of the supply

# 4 Composition

## 4.1 Limits

Unless otherwise provided in an applicable technical specification, the composition of hydrogen delivered to the flight vehicle interface shall be in accordance with the limits given in Table 1 when tested in accordance with the applicable test methods.

**Table 1 — Composition limits**

| Composition | | | Limits | | | |
|---|---|---|---|---|---|---|
| | | | Type 1 (gaseous) | | Type II (liquid) | |
| | | | Grade A | Grade F | Grade A | Grade F |
| Purity | Hydrogen ($H_2$) | volume fraction, % by difference, min. | 99,994 | 99,995 | 99,994 | 99,995 |
| | Para hydrogen (balance orthohydrogen) | volume fraction, %, min. | Not specified | Not specified | Not specified | 95,0 |
| Impurities | Total gases | µL/L, max. | 60 | 50 | 60 | 50 |
| | Nitrogen, water, and volatile hydrocarbons combined | µL/L, max. | 9,0 | 10 | 9,0 | 10 |
| | Oxygen plus argon | µL/L, max. | 5,0 | 1 | 5,0 | 1 |
| | Helium | µL/L, max. | 45,0 | 40 | 45,0 | 40 |
| | Carbon monoxide plus carbon dioxide | µL/L, max. | 1,0 | 1 | 1,0 | 1 |

## 4.2 Procurement

Hydrogen types and grades specified in Clause 1 should be procured in accordance with ISO 14687 or an applicable national standard.

# 5 Fluid sampling

## 5.1 Plan

In order to ensure that the fluid composition complies with the limits specified in this International Standard, a fluid sampling plan should be established by all the involved operators, from the production to the space vehicle interface, and approved by the final user. Such plan shall specify:

 

— the sampling points;

— the sampling procedures;

— the sampling frequency;

— the sample size;

— the number of samples;

— the test methods;

— the responsibilities of any involved operator.

**CAUTION — Hydrogen is an asphyxiant and is volatile. Human contact with liquid hydrogen will result in severe injury. Care should be taken in the handling and storage of liquid hydrogen to prevent contact with the human body and with materials that are not compatible with hydrogen.**

## 5.2 Responsibility for sampling

Unless otherwise provided in an applicable technical specification, the hydrogen delivered to the flight vehicle interface shall be sampled and verified by the supplier responsible for providing the hydrogen to the flight vehicle. The supplier may use its own or any other resources suitable for the performance of the verification tests specified herein unless otherwise directed by the customer.

## 5.3 Sampling points

Unless otherwise specified, sampling shall be conducted at the fluid storage site or the flight vehicle interface.

## 5.4 Sampling frequency

Sampling shall be annually or in accordance with a time agreed upon by the supplier and the customer.

## 5.5 Sample size

The quantity in a single sample container shall be sufficient to perform the analysis for the limiting characteristics. If a single sample does not contain a sufficient quantity to perform all of the analyses for the required quality verification test, additional samples shall be taken under similar conditions.

## 5.6 Number of samples

The number of samples shall be in accordance with one of the following:

a) one sample per storage container;

b) any number of samples agreed upon by the supplier and the customer.

## 5.7 Storage container

Unless otherwise provided by the applicable sampling plan, the fluid storage container shall not be refilled after the time the sample is taken.

### 5.8 Gaseous samples

Gaseous samples shall be a typical specimen from the gaseous hydrogen supply. For safety reasons, the sample container and sampling system must have a rated service pressure at least equal to the pressure in the supply container. Samples shall be obtained in accordance with one of the following:

a) by filling the sample container and storage containers at the same time, on the same manifold, and under the same conditions and with the same procedure;

b) by withdrawing a sample from the supply container through a suitable connection into the sample container. No pressure regulator shall be used between the supply and the sample containers (suitable valves are permissible);

c) by connecting the container being sampled directly to the analytical equipment using suitable pressure regulation to prevent over-pressurizing this equipment.

### 5.9 Liquid samples (vaporized)

Not applicable.

### 5.10 Rejection

When any sample of the fluid tested in accordance with Clause 6 of this International Standard fails to conform to the requirements specified herein, the fluid represented by the sample shall be rejected. Disposition of the rejected fluid shall be specified by the customer.

## 6 Test methods

### 6.1 General

The supplier will ensure, by standard practice, the quality level of hydrogen. If required, alternate test methods are described in Clause 6 of this International Standard. Other test methods not listed in this International Standard are acceptable if agreed upon between the supplier and the customer.

These tests are a single analysis or a series of analyses performed on the fluid to ensure the reliability of the storage facility to supply the required quality level. This can be verified by analysis of representative samples of the fluid from the facility at appropriate intervals as agreed upon between supplier and the customer. Tests may be performed by the supplier or by a laboratory agreed upon between the supplier and the customer.

The analytical requirements for the tests shall include the determination of all limiting characteristics of hydrogen.

### 6.2 Parameters of analysis

The parameters for analytical techniques contained in this section are:

a) purity and impurity contents shall be mole fraction expressed as a percentage (%); by volume unless otherwise noted;

b) calibration gas standards containing the applicable gaseous components may be required to calibrate the analytical instruments used to determine the limiting characteristic levels of fluid;

c) if required by the customer, the accuracy of the measuring equipment used in preparing these standards shall be traceable to an established institute for standards;

d) analytical equipment shall be operated in accordance with the manufacturer's instructions;

 

e) analytical methods not listed in this International Standard are acceptable if agreed upon between the supplier and the customer.

## 6.3 Hydrogen purity

The hydrogen concentration shall be determined by one of the following procedures:

a) by a thermal conductivity analyzer measuring the aggregate impurities which have different thermal conductivities than hydrogen. The analyzer is to be calibrated at appropriate intervals using calibration gas standards. The range of the analyzer shall be no greater than 10 times the difference between the specified minimum percent hydrogen concentration and 100 %. Thus for a 99,5 % minimum hydrogen concentration, the analyzer should have a maximum range of 5 % impurity or from 95 % to 100 % hydrogen;

b) by a volumetric or manometric gas analysis apparatus;

c) by determining the amount of aggregate impurities using the methods in the following paragraphs of this International Standard. The percent hydrogen is the value obtained when this amount, expressed as mole fraction percent, is subtracted from 100 %;

d) by any suitable chromatographic system which effectively measures specific impurities (see 6.2 of this International Standard).

## 6.4 Hydrogen assay for para hydrogen (liquid samples only)

Para hydrogen (percent minimum balance ortho hydrogen) shall be determined by thermal conductivity type in-stream analyzers installed in the supplier’s system and shall be calibrated integrally by the appropriate use of temperature-controlled catalyst beds. The test may be performed only when agreed upon between the supplier and the customer.

## 6.5 Water content

For liquid hydrogen, the water content cannot be determined by sampling, only online measurements are possible. The water content shall be determined by one of the following procedures:

a) by an electrolytic hygrometer having an indicator graduated in cubic centimetres per cubic metre on a range which is not greater than 10 times the specified maximum water content;

NOTE Recombination of oxygen with hydrogen can occur producing a false high reading. Refer to instrument manufacturer’s instructions for proper analytical technique.

b) by a dewpoint analyzer in which the temperature of a viewed surface is measured at the time water first begins to form;

c) by a piezoelectric sorption hygrometer, of which the accuracy of analysis shall be plus or minus 0,1 cubic centimetre per cubic metre or 5 % of the reading, whichever is greater;

d) by a metal oxide capacitor equipped analyzer on a range which is no greater than 10 times the specific maximum water content.

## 6.6 Total hydrocarbon content (THC)

The total (volatile) hydrocarbon content (as methane) shall be determined by one of the following procedures:

a) by a flame ionization-type analyzer. The analyzer shall be calibrated at appropriate intervals by the use of calibration gas standards. The range used shall be no greater than 10 times the specified maximum total hydrocarbon content expressed as methane;

b) by a gas cell-equipped infrared analyzer. The analyzer shall be calibrated at appropriate intervals by use of calibration gas standards at a wavelength of approximately 3,5 micrometres (the characteristic absorption wavelength for C-H stretching). The analyzer shall be operated so that its sensitivity for methane is at least 10 % of the specified maximum total hydrocarbon contents.

## 6.7 Oxygen content

The oxygen content shall be determined by one of the following procedures:

a) by an electrochemical-type oxygen analyzer containing a solid or an aqueous electrolyte. The analyzer shall be calibrated at appropriate intervals by use of calibration gas standards or integrally in accordance with Faraday's Law. The range used should be no greater than 10 times the specified maximum oxygen content;

b) by a heat-of-reaction-type analyzer. The analyzer shall be calibrated at appropriate intervals by the use of calibration gas standards or integrally in accordance with Faraday's Law. The range used should be no greater than 10 times the specified maximum oxygen content;

c) by an analyzer in which oxygen reacts to form a compound which is subsequently measured. The analyzer shall be calibrated at appropriate intervals by the use of calibration standards. The range used shall be no greater than 10 times the specified maximum oxygen content;

d) by a gas chromatograph method such as that described under 6.8 of this International Standard;

e) by a mass spectrometer. The mass spectrometer shall be operated so that its sensitivity is at least 10 % of the specified oxygen content.

## 6.8 Argon, nitrogen, and helium content

The argon, nitrogen, and helium contents shall be determined by one of the following procedures:

a) by a gas chromatograph. This method may be used not only for argon, nitrogen, neon, and helium determination but also for the determination of any other limiting characteristic gaseous components. The analyzer shall be capable of separating and detecting the component with a sensitivity of 20 % of the specified maximum amount of the component. Appropriate impurity concentrating techniques may be used to attain the sensitivity. The analyzer shall be calibrated at appropriate intervals by the use of calibration gas standards;

b) by a mass spectrometer. The mass spectrometer shall be operated so that its sensitivity is at least 10 % of the specified maximum amount of the component.

## 6.9 Carbon dioxide content

The carbon dioxide content shall be determined by one of the following procedures:

a) by a gas chromatograph method such as that described in 6.8 of this International Standard. The technique utilized shall be specific for the separation and analysis of carbon dioxide;

b) by a catalytic methanator gas chromatograph method such as that described in 6.8 of this International Standard;

c) by an analyzer in which carbon dioxide reacts to form a compound which is subsequently measured. The analyzer shall be calibrated at appropriate intervals by the use of calibration standards. The range used shall be no greater than 10 times the specified maximum carbon dioxide content;

d) by a mass spectrometer. The mass spectrometer shall be operated so that its sensitivity is at least 10 % of the specified maximum amount of the component.

### 6.10 Carbon monoxide content

The carbon monoxide content shall be determined by one of the following procedures:

a) by a gas chromagraph method such as that described under 6.8 of this International Standard. The technique utilized shall be specific for separation and analysis of carbon monoxide;

b) by an analyzer in which carbon monoxide reacts to form a compound which is subsequently measured. The analyzer shall be calibrated at appropriate intervals by the use of calibration standards. The range used shall be no greater than 10 times the specified maximum carbon monoxide content;

c) by an apparatus employing a detector tube filled with a color-reactive chemical. The degree of accuracy is dependent on the precision of the measurements and analytical bias of the tube;

d) by a catalytic methanator gas chromatograph method such as that described under 6.8 of this International Standard.

# Annex A
(informative)

## Gaseous chromatography (GC) and mass spectrometer (MS) applications

Gaseous chromatography (GC) should be used as the reference or preferred method to analyze hydrogen impurities, except for water and para hydrogen.

A mass spectrometer plus gaseous chromatography (MS + GC) may be used as an alternative to gaseous phase chromatography to avoid possible interference (especially for the hydrocarbons).

Table A.1 summarizes the applications of these methods for hydrogen. "X" indicates that the method is to be used; "—" indicates that it is not used.

**Table A.1 — Application of GC and MS**

| Characteristic | GC with DID detector on molecular sieve column | GC with FID detector on porapack column (or equivalent) | GC with methanator + FID on porapack column (or equivalent) | MS + GC | MS |
|---|---|---|---|---|---|
| Para hydrogen | — | — | — | — | — |
| Water | — | — | — | — | — |
| Total hydrocarbon content | — | X | — | — | — |
| Argon, nitrogen, helium | X | — | — | X | X |
| Carbon dioxide | — | — | X | X | — |
| Carbon monoxide | X | — | X | X | — |